Bio-energetics of Life Processes
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Lecture – 10
Summary of thermodynamical parameters-II

Welcome back, to the lecture series in bioenergetics for life processes. So, today we are into the 10th lecture or the last lecture of the second week. So, this is our lecture 10 week 2, lecture 5 W 2 L 5. So, as I told you that will be discussing, some of the thermodynamic parameters.

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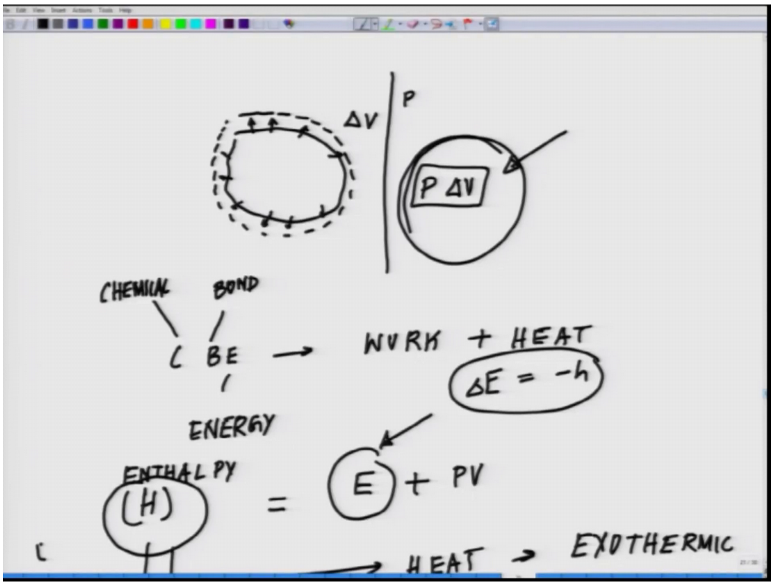

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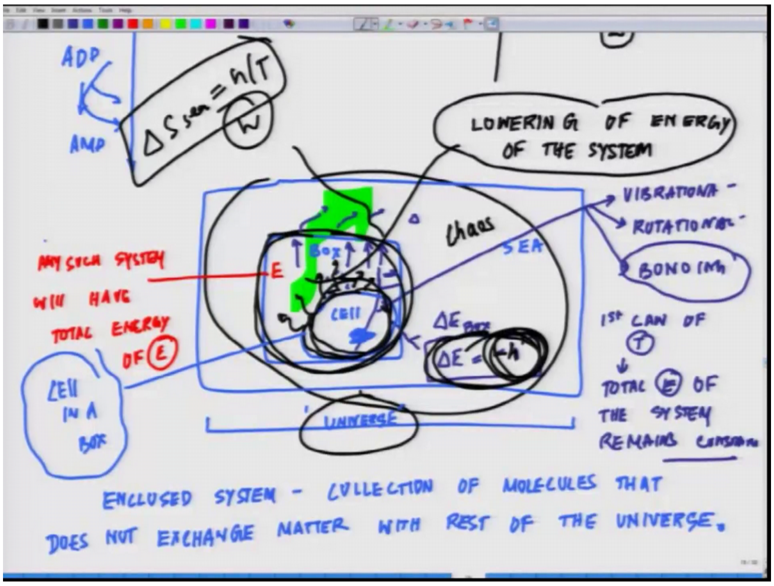

So, coming back where we left in the last class I gave you the analogy of the box and I told you that, when the molecules inside out here, are going through vibrational rotational spin and all sorts of motion, they generate a lot of heat and that heat, slowly get dissipated and eventually at the end, the system in concern lower down it is energy.

Now, we give this concept that, the change in energy is essentially, is the heat which is lost to the surrounding. Now, this brings us to another concept, what we wanted to talk about is, when this molecules are say for example, inside this room I kept on you know the molecules started to push on the walls. So, I mean standing in a room, what will happen is? It will generate a pressure, on the walls of this room and it may even expand it, there may be change in the volume.

So, in other word that kind of displacement could lead to, some form of work could be achieved. So, let us put it here. So, this is the analogy I wanted to give you, and now let me put it down in the text. So, E can also change or the energy can also change during a reaction, due to work being done outside on the outside world.

For example, suppose that there is a small increase in volume, if this is the original one and there is an increase in volume, because of the pressure which is being created. So, a transient increase in volume, something like a delta V change in volume, during the reaction since the walls of the box must push, again a against a constant pressure. So, you have to keep the pressure constant in a under a constant pressure, in the surrounding in order to expand, this does work on the outside world and requires energy and the energy used is P delta V, delta V is the change in the volume. Which according to the first law, must decrease the energy in the box which is the concern boxes here. So, the energy of the box must decrease.

Once again, let me come back where I was so, the energy of the box must decrease in most reactions, the chemical bond energy is converted into chemical bond energy which is C BE, which is chemical bond energy is converted into heat both heat and work, work plus heat. All the chemical bond energy which is broken up, is converted into work and heat and enthalpy H, is a composite function that includes both of these.

So, H or enthalpy, if you remember in the last class I was talking to you about enthalpy H is equal to E plus P V and E framer E is equal to minus H, we have already talked about it that is the heat which is lost, see the previous picture delta e is equal to minus H. So, this is what we talked about, delta E is equal to minus H from here that term is coming.

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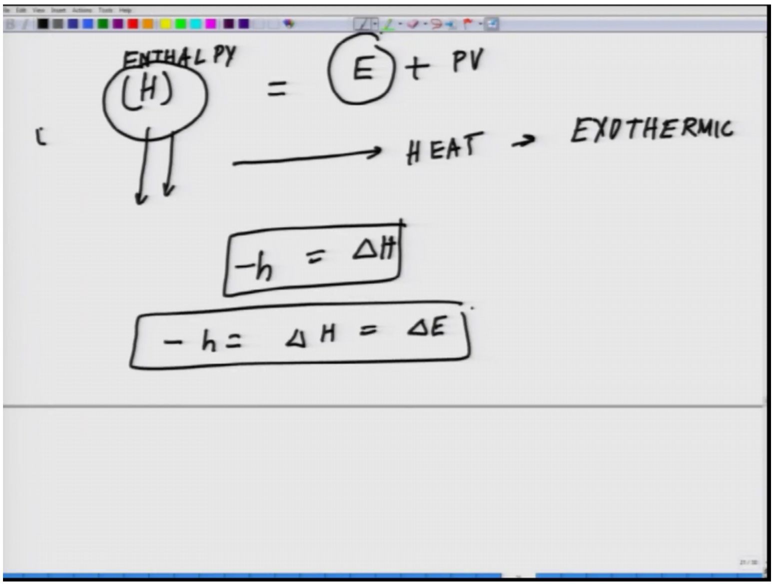

To be rigorous, it is the change in enthalpy delta H in an enclosed system and not the change in energy that is equal to the heat, transferred to the outside world during the reaction. So, the reactions in which H decreases, reactions where H is decreasing such system release heat. Wherever there is a decrease in enthalpy, it will release heat to the surrounding and are said to be exothermic. Similarly, the reaction where in which H increases, absorbs heat from the surrounding and the reverse reaction where are called the endothermic reaction.

So, thus minus H is delta H; however, the volume change is negligible and in most of the biological reactions sort of good approximations, in you hardly see there is a huge change in the volume in the biological reaction. So, what you say is minus H is equal to delta H is equal to delta E. We do not take this term, really into consideration in biological system, because rarely you will see a change in the volume in the biological system, this is one fundamental concept what you have to keep in mind.

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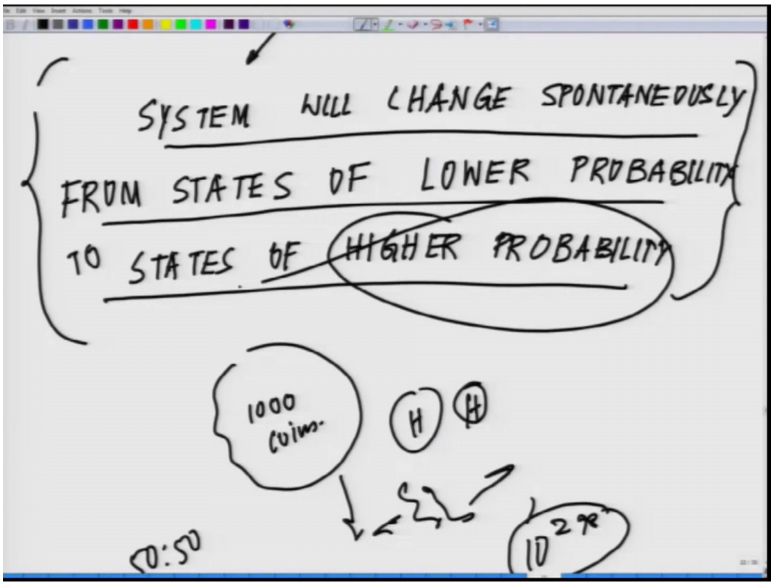

SYSTEM WILL CHANGE SPONTANEOUSLY FROM STATES OF LOWER PROBABILITY TO STATES OF HIGHER PROBABILITY

Now, from here we will move on to the, second law of thermodynamics we have talked about the first law, now we will talk about the second law of thermodynamics. So, second law of thermodynamics could be very easily understood. So, if I tell you a situation, the second law of thermodynamics states that, the system will change spontaneously system from states of lower probability, to states of higher probability. System will change spontaneously from state of lower probability to a state of higher probability what does that mean?

So, if you consider a container in which you have say for example, you have 1000 coins, this is one of the analogies I like to give and all are lying heads up. So, all have heads up, if the container is shaken. So, you shake this whole container in multiple direction, subjecting the coin and the type of random motion, that all molecules experience, due to their frequent collision with each other molecules.

So, you are considering each one as the molecule 1, will end up with about half of the coins-oriented heads down the reason for this reorientation is that, there is only a single way in which the original state of the coin can be reinstated, every coin must lie heads up whereas, there are many different ways about 10 to the power 298 ways, to achieve a state in which there is an equal mixture of heads and tails.

In fact, there are more ways to achieve 50 is to 50 state, than to achieve any other state, each state has a probability of occurrence, that is proportional to the number of ways it can be realized. Now, since states of lower probability are said to be more ordered, than the state of higher probability, the second law of thermodynamic can be restated the universe constantly changes. So, as to become more disordered.

So, what I essentially wanted to point out is say for example, you have 1000 coins as I mentioned, I am again reorienting this fact all are head and you shake the box, what are the chances that, you may again get back all the 1000 coins as all heads most likelihood, that is not going to happen, most likelihood this is a generic remark, we make you know over a cup of coffee you say, there is hardly any chance you are going to get, it hardly any chance you say, you may get it he may be very lucky.

Most likely your possibilities are you may get 50 percent heads and 50 percent tails, as per the if I go by the probability rules so; that means, in order to have that kind of orderliness of all 1000 heads all 1000 tales, you have to do a trade off and the system is constantly heading for a chaos and in between, we create certain degree of order. What does that mean is? That is where I was trying to tell you about the book, by fruits of capra the order out of chaos, it is a very old book and written by a fantastic physicist you may love to read it.

The concept, what I wanted to highlight or borrowed or kind of got inspired by it is very simple. In this whole universe, is as per the second law of thermodynamics it is heading for a chaos, it is spreading out it is becoming more chaotic, yet there are life forms which are evolving which are extremely organized.

So, it is kind of contradiction, that if you see this picture, what was the reason to introduce this picture is. So, if this is that system and this is the surrounding universe, as I mentioned here universe, this universe is heading for more of a chaos, yet the life form is evolving on a reverse direction, where they are becoming more and more of ordered.

So, such orderliness can only be achieved, if you put some intense energy at specific local spots, otherwise the universe is as per the second law of thermodynamics if we follow, the continuously system is heading for more and more towards the disorderliness. So, that is what the second law of thermodynamics critically, tells us or teaches us. System will change you spontaneously from the states of lower probability, to the states of higher probability, and higher probability is more of a chaos. From here we will move on, with giving this idea we will move on to the concept of entropy.

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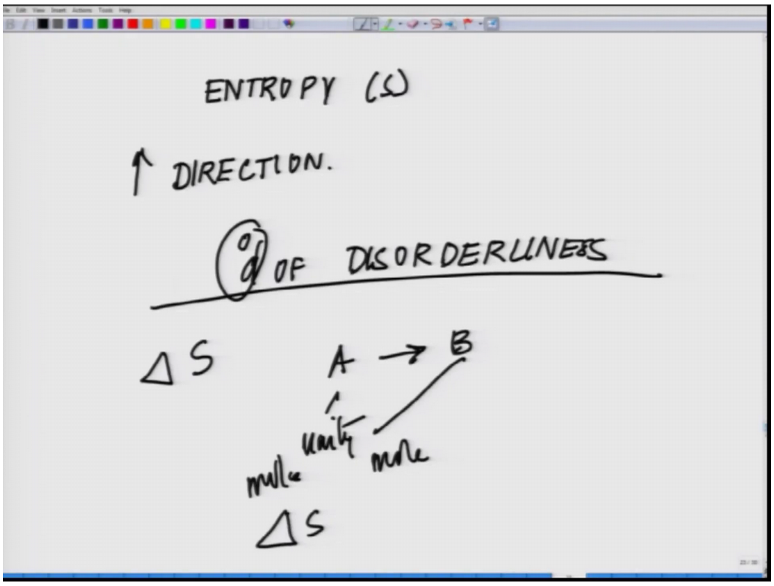

Entropy which is your S, represent by S the second law, but not the first law allows one to predict the direction of a particular reaction. So, we can understand the direction of a particular reaction by the second law, but to make it useful for the purpose, one needs a convenient measure of a probability or equivalently, the degree of disorderliness of the state. So, the degree of, this is your degree of dis or der lines, you needed to figure out the degree of disorderliness of the system.

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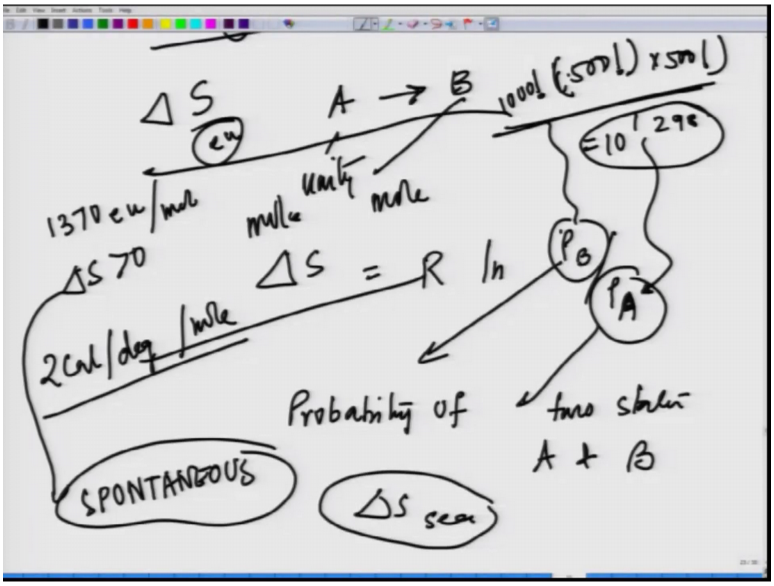

The entropy which is represented by S is a measure it is a logarithmic function of the probabilities, such that change in entropy delta S that occurs when a reaction A converts to B for 1 mole of a to 1 mole of B, again unity is delta S or change in entropy is equal to R the gas constant, natural log sorry where, these 2 terms are probabilities of 2 states A and B and R is the gas constant, which is defined as 2 calorie per degree per mole and delta is the measure of the entropy unit E U.

So, in this case what we have just now mentioned about the 1000 coins, the relative probability of all heads state, A versus half a heads which is half tails state B is equal to the ratio of the number of different ways, that 2 result can be obtained, one can calculate that rho A or this one which is all head, which is 1 and rho B which is this value, which is 1500 sorry multiplied by 500 which is 10 to the power 298 this is I was trying to tell you.

Therefore, the entropy change for a reorientation of the coin, when their container is vigorously shaken and an equal mixture of head and tail is obtained, is R is equal to 10 to the power 298 or about there is another way to express it, which is 1370 EU per mole of such containers which is 6 into 10 to the power 23 containers.

We see that, because delta is defined above is positive for a transition from A to B reactions, with large increase in entropy, are favoured and will occur spontaneously. If delta S is more than 0 these are very spontaneous. So, in other word positive entropy favour the reaction to happen and heat energy cause a random commotion of molecules, because the transfer of heat from an enclosed system to the surrounding increases, the number of different arrangements.

That molecules in the outside world can have it increases their entropy, it can be shown that the release of a fixed quantity of heat energy, has a great disordering effect at low temperature, then at high temperature and that value of delta S, for the surrounding as defined as delta S of the sea, which is the surrounding is precisely equal to the amount of heat transferred to the surrounding from the system, divided by the absolute temperature.

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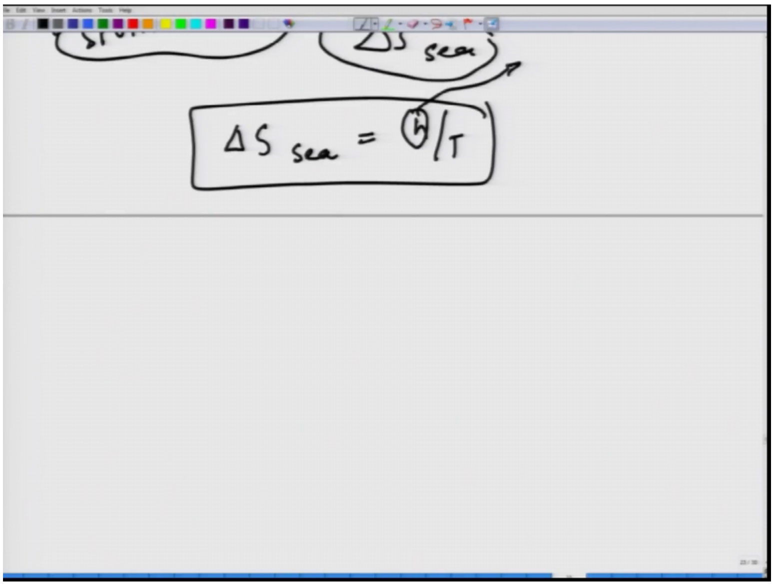

So, in other word you can define delta S of sea is equal to h upon T, where h is heat transferred to the surrounding, you remember this is what we talked about, remember heat this is the heat which is transferred to the surrounding, this h this term which is the heat transfer to the surrounding, divided by the absolute temperature which is the T. So, delta S c equal to h upon T, this is what your the second term entropy talks about. So, in other word, if you revisit this, you will realize the heat energy causes the random commotion of the molecules and because the transfer of heat, from an enclosed system to it is surrounding increases the number of different arrangements, that the molecule in the outside world can have, it increases their entropy.

It can be shown that, the release of a fixed quantity of heat energy has a great disordering effect, at low temperature than at high temperature and during and that value of delta S for the surrounding is defined as delta S for the sea. So, in other word when I am shaking this room and there are vibrations which are going out in the form of, the due to the vibration the heat energy which is liberated outside, that creates that increases the entropy outside the system in other word, for every orderliness what is being maintained? You are actually increasing the entropy of the system outside.

So, in order to maintain orderliness in my body, I am actually increasing the entropy of the system, by generating liberating significant amount of heat, from the system which is disorienting the system outside and that is a very contradictory really beautiful thing, around one hand the universe is expanding, there is a increase in entropy, yet there are life forms which are extremely ordered and they are trying to maintain a balance, between or creating an order out of this whole chaos.

So, these are some of the concepts, which will come very handy as you are realizing we are continuously talking about different energetics mechanism, which are governing much of our life processes, the whole bioenergetics is essentially a treatment of thermodynamics, for the like processes and energy harvesting and the use of energy. So, these are the concept what I wanted to discuss, as the very, very basic fundamental concepts, for of thermodynamics in terms of the biological systems, we will look more into it, as we will to talk little bit more in our subsequent classes, about the Gibbs free energy and correlating it with entropy and enthalpy.

So, as we are almost concluding the second week. So, this week we are supposed to talk little bit about more about, chemosynthesis photosynthesis I am just kind of deferred it a little bit into the third week purposefully because, we will get a lot of time to deal with them, but what is essential is that we understand this basic concepts, whenever I will be writing delta G or you know delta H or delta S, you should be clear that what I am trying to do and please follow this lecture.

So, I could really could not draw whole lot here, you have to really get the concepts very clear. So, listen to the stuff what I have talked today, that will kind of help you to formalize your understanding about, basic understanding about enthalpy and entropy and how we treat a system and the surrounding and the universe.

So, I will close in here thank you and please go through the basics, it will be really helpful and in the next class, as we will move more towards the chemosynthesis, photosynthesis, we will talk a little bit more about, Gibbs free energy and how the orderliness is being maintained in the biological system, against the ever-increasing probability of disorderliness of the universe.

Thank you.